Award Number 99HQGR0071

Controlled Source Study of the Structure of the Seattle and Tacoma Basins – SHIPS99 (Seismic Hazards Investigations of Puget Sound): Collaborative Research with U.S. Geological Survey, Oregon State Un., and Un. of Texas at El Paso

Principal Investigator:

Anne M. Trehu

College of Oceanic and Atmospheric Sciences

Oregon State University

Ocean Admin. Bld. 104

Corvallis, OR 97331-5503

541-737-2655 (voice)

541-737-2064 (fax)

trehu@oce.orst.edu

http://quakes.oce.orst.edu

Abstract:

The heavily populated Puget Basin is underlain by thick sequences of Cenozoic sedimentary rocks that amplify and focus seismic energy, thus increasing ground shaking during an earthquake. The SHIPS (Seismic Hazards Investigations of Puget Sound) project is targeted at acquiring and analysing controlled-source seismic data to be used in modeling and mapping areas of expected strong ground shaking and at better determining the regional velocity structure and tectonic framework of the Puget Sound region, including the location, configuration, and seismic properties of faults that cross this urban region. The first phase of SHIPS was conducted during March, 1998, and involved acquisition of marine multichannel seismic data, expanding spread profiles, and ocean-bottom or onshore/offshore large-aperture recording of marine airgun shots. This project represents the second, onshore stage of SHIPS, which was designed to acquire high-resolution data along an east-west transect through the Seattle metropolitain region. Surveying and permitting of 1000 stations and 38 shot points took the better part of the spring 1999, and was conducted by 5 individuals, 3 of whom were OSU employees. The actual deployment, originally planned for May, 1999, was conducted during September, 1999, and

was very successful. Our objective was to incorporate constraints from this experiment into our larger scale model of the structure of the subducted plate beneath the Straits of Juan de Fuca and Olympic Peninsula while collaborators at UTEP and USGS focussed on modeling the first arrivals and using earthquake data recorded by the array to determine local site response. However, few, if any, clear arrivals were recorded from the lowermost crust and upper mantle during the 1999 SHIPS deployment. This was quite surprizing considering the success of this approach in a similar tectonic setting in northern California and the very strong pre-critical and wide-angle reflections recorded during wetSHIPS. We therefore focussed on further development of our regional model for the the shape of the subducting plate and on implications of those results for understanding the Nisqually earthquake of January, 2001, and other damaging lower plate events that have occurred in the past 52 years. These events seem to initiate at or near the base of the crust of the subducting Juan de Fuca plate, most likely as a result of the decrease in volume and increase in density as gabbro is transformed to eclogite. However, if this were the only cause of the earthquakes, one would expect to record such events along the length of the subduction zone. We note that the large, lower plate earthquakes seem to be clustered at a change in curvature of the subducting plate as the lower plate arch beneath the core of the Olympic mountains unbends and the plate starts to dip east beneath southern Washington and Oregon. We speculate that the earthquakes are a response to the combined stresses from unbending and phase changes. Subducted plate parameters derived from SHIPS can be used to test this hypothesis. If it is confirmed, it implies that large, lower plate events, which have historically been the most damaging events in the Pacific Northwest, should have a restricted regional extent.

Non-technical summary:

The heavily populated Puget Basin is underlain by thick sequences of Cenozoic sedimentary rocks that amplify and focus seismic energy, thus increasing ground shaking during an earthquake. The SHIPS 1999 seismic profile, extending from the Olympic Mountains, across Seattle and into the Cascade foothills, was designed to complement the SHIPS 1998 experiment by increasing the resolution of the models in this area. We have been incorporating constraints from this experiment into our model of the structure of the subducted plate beneath the Straits of Juan de Fuca and Olympic Peninsula while collaborators at UTEP and USGS have been focussing on modeling the first arrivals and on using the data to determine local site response. Our results indicate that the Nisqually earthquake of January 2001and other damaging lower plate events of the past century occurred at or near the base of the crust of the subducting Juan de Fuca plate. We speculate that they represent the response to combined stresses resulting from unbending of the subducted plate on the south flank of the Olympic arch and volume changes due to the transformation of subducted crust from basalt/gabbro to eclogite. Our results provide geometric and velocity constraints to test this speculation.